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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA-16123 (July 2003)
NASA - KSC
Superseding NASA-16123 (March 2003)

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DIVISION 16 - ELECTRICAL

SECTION 16123

FIBER OPTIC CABLE SYSTEM

07/03

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NASA-16123 (July 2003)
NATIONAL AERONAUTICS **NASA - KSC**
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SECTION 16123

FIBER OPTIC CABLE SYSTEM
07/03

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NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This section covers requirements for fiber optic cable systems.

Contract drawings should show the general location of cables and equipment to be placed.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: The following references should not be manually edited except to add new references. References not used in the text will automatically be deleted from this section of the project specification.

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The publications listed below form a part of this section to the extent referenced:

ELECTRONIC INDUSTRIES ALLIANCE (EIA)

EIA 359-A (1985) Standard Colors for Color Identification and Coding

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2002) National Electrical Code

U.S. AIR FORCE TECHNICAL ORDERS (TO)

TO 31W3-10-12 (1986) AF Communications Service Standard Installation Practices, Outside Plant

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FED-STD 595	(Rev B) Colors Used in Government Procurement

1.2 GENERAL REQUIREMENTS

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NOTE: If Section 16003, "General Electrical Provisions," is not included in the project specification, applicable requirements therefrom should be inserted and the following paragraph deleted.

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Section 16003, "General Electrical Provisions," applies to work specified in this section.

1.3 SYSTEM DESCRIPTION

Fiber optic cable shall consist of optical fibers, strength member (or members), and jacketing. Associated components shall include optical fiber connectors, optical patch panels, terminal bay cabinets, and splice closures. Fiber optic cables shall be installed in inner duct in the existing cable duct and manhole system and/or directly buried to the facility. Fiber optic terminal shall be located in existing facility buildings.

All references in this section to cable shall be deemed to mean fiber optic cable.

1.4 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01330, "Submittals," and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control. Include a columnar list of appropriate products and tests beneath each submittal description.

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The following shall be submitted in accordance with Section 01330, "Submittals," in sufficient detail to show full compliance with the specification:

SD-03 Product Data

Manufacturer's catalog data shall be submitted for the following items. Data shall include a complete list of parts, special

tools, and supplies with current unit prices and source of supply.

Optical Fibers
Fiber Optic Cable
Splice Case
Splice Organizers
Pre-Connectorized Cable Assembly
Fiber Optic Terminal Bay Cabinets
Optical Patch Panel

SD-06 Test Reports

Optical Fibers
Fiber Optic Cable
Pre-Connectorized Cable Assembly
Sequential Cable Markings
Single and Multi-mode OTDR Test
End-to-End Attenuation Tests
End-to-End Installed Bandwidth Cable Test

Contractor test reports shall be submitted for approval to the Technical Representative not later than 14 working days after the completion of each test.

Manufacturing, or factory, tests shall be made and results submitted to the Contracting Officer, for approval, prior to shipment of material to the site.

Sequential cable markings along the cable, prior to and after each end of splice point, shall be recorded on the sequential cable form and submitted for approval.

Test results shall be submitted on all installed fiber cabling before and after each pre-connectorized cable assembly splice is completed.

All test results shall be submitted prior to final testing.

End-to-End Attenuation Test reading shall be included as the test reference loss as indicated.

End-to-End bandwidth cable test shall be made at the completion of the testing.

SD-07 Certificates

A Quality Assurance Plan shall be submitted for fiber optic cable systems consisting of detailed procedures defining methods to ensure compliance to contract drawings and specifications by drawing control, inspection and procurement records, test plan showing when and how each system will be tested, material testing, and certification records. Test plan shall be submitted to the Technical Representative for approval at least 30 days prior to the start of testing.

PART 2 PRODUCTS

2.1 FIBER OPTIC CABLE DESIGN

Design of this cable shall be in accordance with the requirements of cable specification 79K28125 except where noted.

All fiber shall be of the same type, specification and manufacturer. Order of sequence of fibers in the cable is Multimode (MM) first and Single Mode (SM) last. Outer protection to the cable structure may be provided for building, direct burial, rodent or lightning conditions. Riser and plenum cable shall be in accordance with NFPA 70, Article 770.

Primary protective coated optical fibers, both MM and SM, shall be individually buffered with a color coded substance for individual fiber identification and ease in handling. Maximum outside diameter of the buffered fiber shall be less than 300 micrometer. Fibers and the buffer tubes shall have pigmented inking formulas to provide vivid colors that can be distinguished rapidly. Type and size of the cable shall be identified on the design plans. Each cable shall contain multimode (MM) and/or single mode (SM) fibers in bundles within loose buffer tubes. In the fiber cable, the MM fibers are included with the SM fibers in a ratio of 1 to 1, 2 to 1, or 5 to 1.

Colors shall be in accordance with EIA 359-A. Munsell Notation for pink shall be 1R-4R 6.5-8.5/10 up and for aqua shall be 2BG-8BG 6.5-8.5/6-10. Fibers in each loose buffer tube shall be color coded using ten standard vivid colors together with a white or black stripe to form additional color combinations in the eleventh position and above; as well as pink and aqua, as alternates, for position eleven and twelve, respectively, as follows:

Blue(Bl), orange(O), green(G), brown(Bn), slate(S), white(W), red(R), black(Bk), yellow(Y), violet(V), blue-white(Bl-W), or pink(P), orange-white(O-W), or aqua(A).

Loose buffer tubes shall follow the same coloring as above and shall continue with the colors of green-white (G-W), brown-white(Bn-W), slate-white(S-W), red-white(R-W), black-white(Bk-W), yellow-white(Y-W), and violet-white(V-W).

Where a black stripe is utilized in place of the white stripe, the last four colors above are:

White-black(W-Bk), red-black(R-Bk), yellow-black(Y-Bk), and violet-black (V-Bk).

A metallic armor shall be used where direct buried cable is specified for additional tensile strength, rodent protection and high crush and moisture resistance.

2.2 CABLE IDENTIFICATION SYMBOL

First of three lines on the ID symbol shall employ the following 5

characters:

First Three Characters: First three characters (from left to right) shall denote the number of active optical fibers in the cable.

Fourth Character: Fourth character shall be a slash.

Last Three Characters: Last three characters shall denote optical transmission windows which the optical fiber can support. These windows are defined as follows:

a. An "A" shall be indicated denoting a window at a wavelength of 850 nanometers (nm) with an attenuation of 4 dB/kilometer and a bandwidth of 800 MHz-kilometer. Character shall be an "O" when these requirements are not met.

b. A "B" shall be indicated denoting a window at a wavelength of 1,300 nanometer with an attenuation of 1.0 dB/kilometer and a bandwidth of 1,000 MHz-kilometer. Character shall be an "O" when these requirements are not met.

c. A "C" shall be indicated denoting a window at a wavelength of 1,550 nanometer with an attenuation of 0.7 dB/kilometer and a bandwidth of 1,000 MHz-kilometer for multimode and 0.4 dB/kilometer or less for single mode. Character shall be an "O" when these requirements are not met.

Two lower lines of the cable ID symbol shall indicate multi-mode or single mode fibers, the cable number and the fiber count:

Example:	216/OBC	Identifies the number of optical fibers (216) and the optical transmission window (OBC - see preceding paragraph).
	FM05 : 1-108	Identifies Multi-Mode Fiber Cable 05 with MM Fibers as numbered.
and	FS05 : 1-108	Identifies Single Mode Fiber Cable 05 with SM Fibers as numbered.

2.3 REPLACEMENT CABLE

In addition to the cable sections, a reel of each size and type of the manufacturer's furnished cable, not less than 0.5 kilometers, shall be provided.

2.4 SPLICE ORGANIZERS AND CLOSURES

Single mode or multi-mode fibers shall be fusion spliced with a protective sleeve covering and stored in an organizer with a minimum of 18 inches 450 millimeter spare fiber in the buffer tubing and coiled. Single mode fibers shall be spliced last in the splice tray.

Fiber splice shall be completed in a stainless steel housing or equivalent splice case outer closure. A rigid plastic inner closure and an organizer assembly capable of holding (6) 12 or (6) 24 fiber protected splice trays as required.

Space between the inner and outer closures shall be filled with encapsulating fluid. End plates shall be factory drilled to fit the cable(s) outer diameter.

2.5 PRE-CONNECTORIZED CABLE ASSEMBLY

Contractor shall supply a factory assembled pre-connectorized cable assembly to interface with the patch panel bulkhead feed-through receptacle. Fiber in the pre-connectorized cable assembly shall be manufactured by the same specifications and manufacturer as in the multi-fiber cable. Both the cable assembly connector and the bulkhead receptacle shall be manufactured by the same manufacturer. Contractor shall supply and install dust caps for all terminated fibers.

Connector/cable interface on both the multimode and the single mode assemblies shall withstand a tensile force of 25 pounds 110 Newton without detrimental affects on the loss characteristics of the fiber.

Before the pre-connectorized cable assemblies are shipped to KSC, a Contracting Officer's representative shall visit the assembly and polishing site to inspect the assembly and quality control procedures as well as random samples of the finished assemblies.

2.5.1 Multimode

Connector and feed-through adapter (coupler) used to terminate and test the fibers shall be the equivalent of the AT&T enhanced ST connector and coupling. Coupling shall be made of metal and shall be the bayonet/flange type. Connector shall have a metal housing and a ceramic ferrule. Connector shall be terminated utilizing heat cured epoxy on a three (3) meter length of multimode fiber jacketed as a single fiber cable. Each connector half shall exhibit a loss of 0.5 dB or less. Additional manufacturers include 3M and Porta Systems.

2.5.2 Single Mode

Connector and feed-through adapter (coupler) used to terminate and test the fibers shall be the equivalent of the AT&T enhanced ST connector and coupling. Coupling shall be made of metal and shall be the bayonet/flange type. Connector shall have a metal housing and a ceramic ferrule. Connector shall be PC polished finish and terminated utilizing heat cured epoxy on a three (3) meter length of single mode fiber jacketed as a single fiber cable. Each connector half shall exhibit a loss of .5 dB or less. Return loss for each connector shall be -30 dB or better. Additional manufacturers include 3M and Porta Systems.

2.6 OPTICAL PATCH PANEL ASSEMBLIES

All cable terminations shall be made in optical patch panel assemblies.

Patch panel assemblies shall be the pre-assembled ["Optima Instrument"] [_____] chassis and associated rack-mounting hardware manufactured by the [Optima Enclosures] [_____] or equivalent.

To facilitate the transition between outside plant cable and the pre-connectorized cable assemblies, the fibers shall be fusion spliced and housed in a [Celwave-Valtec] [_____] splice tray, [Part No. C0081377] [_____] or equivalent. Splice tray shall be positioned in the optical patch panel assembly as indicated. Attenuation of the fusion splice is not to exceed 0.2 db. Fusion splice shall be covered with a protective sleeve.

2.7 FIBER OPTIC TERMINAL BAY CABINETS

FOT cabinets shall be [Optima Enclosure's "Optima Vertical Cabinet," Model No. R-771924R (front recess only)] [_____], or equal. Cabinet's frame shall consist of vertical and horizontal tubular aluminum extrusions with a minimum wall thickness of 0.150 inches 3.81 millimeter. Front to rear aluminum extruded corners shall be at least 0.125 inches 3.18 millimeter in thickness. Rear door, top panel, and side panels shall be a minimum of 18 gage 1.3 millimeter steel. Cabinet shall be provided with 14 gage 1.9 millimeter steel, 0.281 inches 7.14 millimeter punched panel/chassis mounting rails permitting recessed installation of equipment. Cable entry and exit holes shall be placed as indicated. Dimensions of cabinet and associated cabinet hardware shall be as noted.

Cabinet shall be gray in color in accordance with FED-STD 595.

[Optima accessories needed for FOT cabinets:

1. Connection Kit HW-67 for adjoining cabinets

2. Doors:

   Solid rear door, typical, Model No. D-7719nn

   Plexiglas front door, typical, Model No. 2D-7719nn-K

   "nn" is replaced by RH or LH, depending on location. Specific door ordering information shall be as indicated.]

PART 3 EXECUTION

3.1 INSTALLATION

Cable construction work shall be performed by construction personnel who have had at least 3 years experience in placing cables in conduit, cable trays, and underground duct systems.

Fiber optic cable splices, terminations and testing shall be made by journeymen cable splicers who have had a minimum of one year experience in splicing and terminating fiber optic cables.

Each individual who is to perform fiber optic cable splicing may be required to perform a minimum of one acceptable sample splice and

termination. Sample splices and terminations shall not be incorporated in the job.

Contractor shall give a school of instruction in the presence of the Contracting Officer, or his representative, to all individuals who are to perform cable construction, splicing, inside installation, terminating and testing work on this job. This schooling shall be comprised of a careful and detailed review of construction techniques, splicing work, and termination according to the various procedures specified for use on this job. The school is to ensure the journeymen are familiar and understand all aspects of material, equipment, techniques, and procedures related to this project. This school shall consist of a minimum of eight hours of instruction. Instructors shall have had a minimum of three years experience in the splicing or terminating of the types of cables on which they are performing the instruction.

3.2 FIBER SPLICES

Outside plant fiber splices shall be fusion type and made along the fiber route where indicated. Splices shall exhibit an insertion loss not greater than 0.2 dB. All splice measurements shall be made at 1300 nanometer, plus or minus 5 nanometer. All splices shall be mounted in trays. Number of splices shall not be increased.

Completed fusion type splice shall be covered with a protective sleeve (heat shrink type or approved equal) to restore the protective properties of the fiber coating and buffering. Deviations to the splice, location and pulling plan will be permitted, upon approval by the Contracting Officer.

All fiber colors shall be continuous from end to end. No switching or staggering of color scheme within the cable at splice points shall be allowed. Fibers shall be spliced in order with multi-mode fibers identified first and single mode fibers at the end.

Cables shall be brought out of the manhole in a controlled environment to perform the fiber fusion splice operation. Complete the splice by returning the cable to the manhole and routing the cable around the manhole interior in a neat and orderly manner such that the excess cable does not impede future entrance and utilization. Cable shall be secured at regular intervals.

3.3 WORK IN MANHOLES AND CABLE VAULTS

Contractor shall be responsible for ensuring that safe operating procedures are followed, work equipment is adequate, and personnel have received proper training. All atmospheric tests will be conducted by others prior to Contractor personnel entering a manhole or vault. Safety equipment will be inspected and approved by an authorized representative of the Contracting Officer.

No smoking shall be permitted. A safe atmosphere shall be positively determined.

Open manholes shall be protected by fences, railings, signs, flags, or

lights, as applicable. Removal of manhole covers shall be performed by two men using hooks and employing proper lifting techniques. All manhole covers in the immediate vicinity of the duct system where work is to be performed shall be removed to permit adequate ventilation.

Each time work is begun, excessive water shall be removed or pumped from the manhole vault or duct run, as required, prior to personnel entrance.

A manhole entry permit shall be required for every manhole entry. This permit will be issued by EG&G Environmental Health.

Vapor tests shall be performed to ensure that the presence of explosive gases is below dangerous concentration levels less than 25 percent by volume.

Above environmental tests shall be performed each time work is started or at the initial crew change and shall be repeated in a time interval not to exceed 8 hours. When prolonged forced ventilation is required, the time interval for additional tests shall not exceed two hours.

Two persons shall be present during manhole operations: one man enters the manhole, the other shall remain outside. The outside person shall be equipped with a communication device to call for help if necessary.

When environmental tests indicate atmosphere is not safe, blowers or ejectors shall be used to clear all manholes or cable vaults of vapors, fumes, and gases to a safe level.

Blowers or ejectors shall be operated continuously while work is being performed and until work is completed.

Blowers or ejectors shall not be placed in the manhole or cable vault but shall be located on the surface at a distance not less than 5 feet 1500 millimeter from the open manhole or cable vault to assure a safe operating atmosphere.

Ladders of the proper length and type (wood or fiberglass) shall be used for entry into manholes.

Contractor shall locate all engine driven equipment downwind from manholes.

3.4 CABLE PLACEMENT

Contractor shall be responsible for surveying the installation are to determine obstacles to installation and the exact locations for cables and equipment to be installed. Any conditions that would preclude installation of cables and equipment in the location shown on the contract drawings shall be immediately reported to the Contracting Officer.

Prior to any excavation, the Contractor must obtain excavation permits in accordance with the contract schedule.

3.4.1 Buried Cable Installation

3.4.1.1 Cable Placement

Buried cable installation refers to the placement of cables directly in the ground without protection other than their own outer coverage jackets. Overall buried cable installation may include manholes and hand holes, for splicing, terminating and pull-through purposes.

Location of the cable splice overlaps shall be as noted. Contractor shall ensure that all cable ends are sufficiently long before cutting.

A 6-mil 0.15 millimeter thick orange color warning tape shall be placed 12 inches 300 millimeter above the cable. Tape shall contain 1-inch 25 millimeter high lettering with the words: "CAUTION! BURIED CABLE BELOW" every 5 feet 1500 millimeter along the tape.

3.4.1.2 Field Staking

When staking the cable plow or trench line, stakes shall be placed at least every 100 feet 30.5 meter in level country and more frequently in rolling country or in dense vegetation, so that the construction force can sight at least two successive stakes at all times. Stakes should be placed at changes in direction, the beginning and end of all turns should be staked clearly. Where existing buried cable is encountered within 2 feet 600 millimeter of the proposed line, the distance between stakes shall be decreased to a minimum of 10 feet 3.05 meter. When possible, stakes should project above the vegetation along the line. When a road or other crossings are involved, stakes should be placed at both extremes of the right-of-way.

Lateral Stake Placement. A stake, with the appropriate number or explanation noted on it, should be used to show the location of the items listed below:

a. Each caution point, such as underground utility crossings and culverts.

b. Miscellaneous points, such as physical cable protection.

c. Buried cable warning sign locations.

3.4.1.3 Method of Cable Placement

Method used in placing the cable will depend on the exact location of the route, obstructions encountered, soil conditions, and topography of the route. Method which best suits the local conditions and which produces the least amount of disturbance or damage to existing utilities and surrounding areas should be used. Under certain conditions, combinations of placing methods may be advantageous. All direct buried cable shall have a warning tape placed above it as indicated.

Depth of buried cable in soil measured from the top of the cable to the surface of the ground shall be a minimum of 30 inches 770 millimeter, when

crossing existing utilities, hand excavation shall be accomplished no less than 4 feet 1200 millimeter on each side.

Contractor must be familiar with the characteristics and capabilities of the plow and other equipment used in the installation of buried cable plant.

3.4.1.4 Open Trench Method

PROCEDURE: When placing cable by the open trench method, observe the following:

a. Ensure that the trench is free of all rock and debris.

b. Cable is to be pulled from cable reel truck or dolly and placed in the trench by hand.

c. Cable is to be placed in trench as soon as practical and backfilled immediately to avoid cave-in, and provide safe operational conditions.

d. Detail an inspector to walk closely behind the cable reel dolly. Inspector shall make sure that the cable lies flat on the trench bottom, and is placed at the required minimum depth. He shall be familiar with the standard signals and shall walk in a position where he can be clearly seen, so that placing operations may be stopped when necessary.

e. Cable is to be pulled by hand on each end simultaneously, to remove excess slack, prior to backfilling.

f. Trench is to be backfilled in six-inch 150 millimeter lifts to ensure proper fill. Compact each backfill lift with hand tamp tools. First lift is to be hand tamped prior to placing the cable.

3.4.1.5 Direct Plow Method

PROCEDURE: When placing cable by the direct plow method, observe the following:

a. Ensure that the plow is clear of any obstruction which may damage cable. Insure all rollers on the tractor and on the plow turn freely and are properly located.

b. Detail a man on the reel hand feeding the cable at all times to insure no damage is done to the cable due to excess tension.

c. Detail an inspector to walk closely behind the plow. Inspector shall inspect the cable for any blemish or damage, and insure a free and continuous flow of the cable from the reel to the plow. Inspector is to ensure that the cable is plowed at the minimum required depth. He shall be familiar with the standard signals and shall walk in a position where he can be clearly seen so that placing operations may be stopped when necessary.

3.4.1.6 Compaction

Following the plowing in or trenching of wire or cable, the plow slot must be compacted. The following method of compaction is recommended: Run the tractor track or tire along and immediately adjacent to both sides of the plow slot; fill in any ground depressions which may develop with earth to form a mound over the center of the plow slot; and then run the tractor tire over the center slot. Different soil conditions may warrant that other methods of compaction be employed.

3.4.1.7 Handling and Care of Materials During Construction

It is most important that extreme care be exercised in handling materials during construction. As required, the contractor must provide competent supervision on the plow at all times to ensure that the buried cable is fed through the plow into the ground at zero tension. Under no circumstances should tension be allowed to develop in the cable.

Whenever the plow is stopped, sufficient cable is to be unreeled to guard against sudden jerks when the plow is started.

Extreme caution must be exercised to ensure that the plow is not backed up while the blade is in the ground. Experience has shown that cable can be severely damaged by the plow backing up even a slight amount. During the plowing operation, the plow may strike a buried object or rock that would stop the equipment and necessitate removal of the plow from the ground. If this should occur, the plow should be removed carefully without backing up. Should it be necessary to back the plow, the cable must be uncovered a sufficient distance back from the plow for inspection by the Government to determine if there is any damage. Any damage shall be immediately reported to the Contracting Officer. Damages shall be repaired or replaced as directed by the Contracting Officer.

3.4.2 Underground Cable Installation

Inner duct assignment of individual cables is shown on the contract drawings. Cables shall not be placed in ducts other than those specified.

Adequate care shall be exercised when handling and storing reels of cable to prevent damage to the cable. Cable with dents, flat spots, or other sheath distortions shall not be installed.

3.4.2.1 Securing Cable

Immediately after cable placement, a permanent identification tag as indicated shall be attached to visible cable sections. Cables shall be checked to ensure that the markings are intact.

Cables and equipment shall be supported and secured as indicated. Where the specific method of support is not shown, adequate supports and fasteners shall be used to secure cables and equipment in position. Metallic supports and fasteners shall have a corrosion resistant finish. All cables shall be routed along the interior sides of manholes.

Two or more cable hooks are required per manhole.

Clamps and Ty-Raps shall be used as necessary to properly secure the cable.

3.4.2.2 Bending

Caution shall be used when bending cable to avoid kinks or other damage to the sheath. Bend radius shall be as large as possible with a minimum of 10 inches 250 millimeter. Minimum radius shall be increased when necessary to meet cable manufacturer's recommendation. Cables shall not rest against the edge of the duct conduit mouth, the 30-inch 770 millimeter manhole opening or other sharp edges.

Cable shall be pulled and spliced in the manner and at the locations indicated.

3.4.2.3 Pulling

Pulling lines shall be attached to both cable ends when cable is destined for bi-directional pull, and fitted with factory-installed pulling eyes as shown in TO 31W3-10-12. Cables not equipped with a pulling eye shall have the pulling line attached to the cable end by means of a cable grip, installed as shown in TO 31W3-10-12. Core hitches shall not be used.

Cable reels shall be located and aligned so that the cable is payed out from the top of the reel into the duct or conduit in a long, smooth bend without twisting. Cable shall not be pulled from the bottom of the reel. A cable feeder guide of proper dimensions shall be used at the mouth to guide the cable into the duct or conduit.

Rigging shall be set up at the pulling end so that the pulling line and cable exit on a line parallel with the duct or conduit to prevent either from rubbing against the edge or mouth. Cable ends shall not be pulled around sheave wheels. When the sheave or pulley cannot be positioned to obtain sufficient cable end slack for proper racking and splicing with the pulling line attached to the end of the cable, a split cable grip may be used to obtain the necessary slack.

3.4.2.4 Lubricant

Adequate pulling lubricant, ["Polywater" Lubricant F] [_____] or equal, shall be used to minimize pulling tension and prevent sheath damage when pulling cables into ducts and conduits. Lubricant shall be applied to the cable sheath with a lubricator. When pulling has been completed, the exposed cable ends shall be wiped clean of lubricant.

Lubricants shall be certified by the lubricant manufacturer to be compatible with and intended for use with plastic-sheathed cables. Soap and grease type lubricants shall not be used.

All equipment and the pulling set shall be carefully checked to minimize interruptions once pulling begins. Cable shall be pulled as far as possible without stopping until the required amount of the cable has been placed. When for any reason the pulling operation must be halted before

the pull is completed, the tension of the pulling line shall not be released. When pulling is resumed, the inertia of the cable shall be overcome by increasing the tension in small steps a few seconds apart until the cable is in motion. Cable shall be payed from the top of the reel by rotating the reel in the feed direction at the rate of pull. Cable shall not be stripped off the reel by pulling.

3.4.2.5 Damage and Defects

It shall be the Contractor's responsibility to ensure by means of a tension monitoring device that the cable pulling procedures being used do not exceed the maximum pulling tension that may be applied to the cable to be pulled into a conduit section. Any damage to the cable due to exceeding the maximum tension will require a new cable furnished by the Contractor.

Cable shall be carefully inspected for sheath defects or other irregularities as it is payed out form the reel. When defects are detected, pulling shall stop immediately and the cable section shall be repaired or replaced at the discretion of the Contracting Officer. A system of communications shall be maintained between pulling and feed locations so that pulling can be stopped instantly, when necessary.

When making pull-throughs, a man shall be used in the intermediate manhole to guide the cable into the next duct section. Proper rigging shall be used in the intermediate manhole to keep the pulling line and cable aligned with the exit duct to prevent the line or cable from rubbing against the edge of the duct. Cables in pull-through manholes shall be set up and racked before the cable ends in adjacent manholes are set up and racked.

Cable ends pulled into manholes, vaults, or terminal locations that are not to be racked or otherwise permanently positioned immediately shall be tied in fixed positions to prevent damage to the cables and provide adequate working space.

3.4.2.6 Seal

Ducts or innerduct in which cable is placed shall be sealed with urethane foam duct seal. This material shall be inserted between the cable and the duct or innerduct of which it is in, between the innerduct and the duct, and in all unused innerduct, in order to prevent damage to the cable sheath and to prevent the entrance of dirt or water into the manhole or vault.

Cables shall be provided in continuous lengths as required to accomplish the required installation without splices from termination to termination, except where field splices are specifically shown.

3.4.3 Cabling Installation in Cable Trays

Communication cables shall not be installed in the same cable tray with AC power cables.

Cables placed in cable trays shall be installed in a neat and orderly manner and shall not cross or interlace other cables except at breakout points.

Cables in vertical trays shall be individually retained with [Ty-Rap] [_____] straps or equal, a maximum of 6 feet 1800 millimeter on center.

3.4.4 Cable Delivery

Replacement cable reels shall be delivered to the Government as directed by the Contracting Officer.

3.5 GROUNDING SYSTEMS

Cables shall be grounded at each termination point or as indicated.

3.6 TESTING

All test equipment, test procedures, and testing techniques shall be specified in the quality assurance plan and will require approval prior to execution. Tests shall be conducted by the Contractor in accordance with the approved Quality Assurance Plan. Purpose of this testing is to verify that the installed fiber optic cable system meets all specified attenuation and bandwidth requirements and is capable of being used for its intended purpose. Field tests shall be witnessed by the Government Technical Representative. Government Technical Representative shall be given at least 20 working days notice prior to performing each test.

3.6.1 Quality Assurance Plan

Contractor shall prepare a quality assurance plan which provides a detailed outline of all testing to be accomplished. Quality assurance plan shall address whether cladding modes have been stripped prior to testing, source wavelength, peak, spectral width full width/half maximum (FWHM), mode structure, fiber end preparation, and bandwidth measurements of fiber links both greater and less than 1 kilometer. Quality assurance plan shall include, as a minimum, a schedule of when tests will be performed relative to installation milestones, specific test procedure that will be used, a list of test equipment that will be used, manufacturer, model number, range, resolution accuracy, and shall conform to the specified requirements of other sections of this specification.

3.6.2 OTDR Test

Contractor shall perform Optical Time Domain Reflectometer (OTDR) tests during cable installation splice operations. Fiber alignment shall be made according to the OTDR read out to minimize the loss as the fusion splice is completed. A 1 kilometer (minimum) fiber delay line is required between the OTDR and the first connector and after the far end. Splices not conforming with the maximum attenuation requirements shall be reworked to conform. When after three attempts, the specified value is not obtained, the splicing operation shall be completed with the approval of the Contracting Officer and so noted on the test record. Testing shall be performed in both directions.

3.6.3 Installed Signature

An end-to-end signature trace shall be provided for all completed fibers. Trace shall show the entire cable loss including the fiber, all splices, cable assemblies and all delay lines. Acceptance shall be based on maximum allowable loss through the patch panels of 1.2 dB for the mated pair of connectors and the panel splice.

3.6.4 End-to-End Attenuation Tests

After terminations have been completed, each fiber shall be measured end-to-end from both directions. Attenuation shall be measured at 1,300 nanometer (nominal) wavelength using the insertion-loss method with the power launched into a short reference fiber utilizing the same type connectors on each end. Reference fiber shall be connected to the optical transmitter, wrapped around 1/2 inch 12 millimeter diameter mandrel 5 times as a minimum and connected to the same type connector as the system to be tested. A similar connector and short reference fiber shall be connected to the poser meter and the reference measured. Transmitter and power meter shall be connected to opposite ends of the system to be tested. Attenuation shall also be tested for the 1550 nanometer wavelength.

Measured loss shall be less than the calculated loss where the length under test in kilometers multiplied by 1 dB/kilometer added to the number of splices multiplied by .2 dB added to the number of connector halves multiplied by .5 dB for MULTIMODE and multiplied by only .5 dB/kilometer for SINGLE MODE fibers.

3.6.5 End-to End Bandwidth Tests (Multimode Only)

End-to-end bandwidth shall be measured utilizing the frequency domain method. Bandwidth shall be measured in both directions. Bandwidth at -3 dB optical power of each optical fibers in the cable shall be a bandwidth length product greater than 1 GHz-kilometer within a peak optical emissive region of 1280-1330 nanometer. This test shall be made at the completion of all other testing. Calculated bandwidth in megahertz (MHz) shall be equal to or greater than 1 GHz-kilometer for lengths less than 1 kilometer and shall be equal to or greater than 1 GHz-kilometer divided by the length in kilometers for lengths greater than 1 kilometer.

3.6.6 Test Results

Each test sheet shall have a sign-off blank for the Contractor as well as the Contract Technical Representative. Copies of the completed test forms or test results shall be delivered according to the shop drawing procedure.

Contractor shall maintain an accurate test record during all Field Tests. Samples are attached at the end of this section. Use of these sample formats are not mandatory.

3.7 TEST EQUIPMENT

A quality assurance plan shall be submitted.

Test equipment used for verifying installation testing shall be calibrated by a certified testing company within three weeks of use and meet the following requirements.

3.7.1 Optical Time Domain Reflectometer (OTDR)

Operating wavelengths: 1,300, plus or minus 20 nanometers

Attenuation Range (one way): minimum 15 dB at 1,300 nanometer

Attenuation Resolution: 0.01 dB

Accuracy: plus 0.5 dB.

Display: OTDRs shall have digital readout capability and shall have a means of providing a permanent record, strip chart or photograph.

3.7.2 Attenuation Measurement Test Set

An attenuation measurement test set shall consist of an optical power meter and an optical power source. Attenuation measurement test set must be traceable to NBS standards for stable optical source. Meter may be analog or digital. The following requirements shall apply:

Operating wavelengths: 1,300, plus or minus 10 nanometers

Attenuation Range: at least 30 dB or better at 1,300 nanometer

Attenuation Resolution: 0.01 dB

Accuracy: Accuracy of the attenuation measurement test set shall be plus or minus 5 percent.

Optical source shall be capable of coupling sufficient power into the fiber so that the light received at the meter is within the meter detectability limits.

3.7.3 Bandwidth Measurement Equipment

Operating wavelengths: 1,300, plus or minus 10 nanometers

Bandwidth range: minimum 1000 megahertz

Bandwidth Resolution: 1 megahertz

Accuracy: plus or minus 0.5 megahertz

Measurement Method: Swept Frequency

SAMPLE DATA FORM

FACTORY CABLE DATA (REELED)

CABLE MFG.:________________________DATE:________________
ADDRESS:___________________________REEL NO.:____________
CABLE IDENTIFICATION:______________REEL LENGTH:_________km.

FIBER CA NO	TUBE AND FIBER COLOR	BANDWIDTH (MHZ-km)1300nm	ATTENUATION (dB/km) 1300nm	NUMERICAL APERTURE

TEST CONDUCTOR:____________________________DATE:____________

CONTRACTING OFF. REP.:_____________________DATE:____________

SAMPLE DATA FORM

PRE-CONNECTORIZED CABLE ASSEMBLY

CABLE MFG.:____

ADDRESS:____

ASSEMBLY IDENTIFICATION:____

LENGTH:___________km (___________ft.) LOT NO.____________________________

ASSEMBLY NUMBER	ATTENUATION (dB) 1300nm	ASSEMBLY NUMBER	ATTENUATION (dB) 1300nm

TEST CONDUCTOR:____________________________________DATE:______________

CONTRACTING OFFICER'S REP.:________________________DATE:______________

SAMPLE DATA FORM

SEQUENTIAL CABLE MARKINGS

FROM BLDG.:_____TO BLDG./END POINT:_____
LENGTH:_____km. CABLE NUMBER:_____

BUILDING /MANHOLE	LOCATION	READING	DISTANCE
	START POINT		
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
	END POINT		km
TOTAL (START TO END)			km

TEST CONDUCTOR:_____DATE:_____

CONTRACTING OFFICER'S REP.:_____DATE:_____

SAMPLE DATA FORM

SINGLE AND MULTI-MODE OTDR TEST

1300nm OTDR

PICTURE

	TEST LOCATION:_____
	_____
	SPLICE LOCATION:_____
	_____
	VERT.= _____dB/div.
	HORZ.= _____km/div.
	LENGTH TO SPLICE_____km.
	LOSS TO SPLICE_____dB.
	FIBER LENGTH TO END_____km.
	FIBER LOSS TO END_____dB.

SPLICE LOSS_____dB. TUBE_____COLOR_____

CABLE NUMBER_____FIBER COUNT_____

1300nm OTDR

PICTURE

	TEST LOCATION:_____
	_____
	SPLICE LOCATION:_____
	_____
	VERT.= _____dB/div.
	HORZ.= _____km/div.
	LENGTH TO SPLICE_____km.
	LOSS TO SPLICE_____dB.
	FIBER LENGTH TO END_____km.
	FIBER LOSS TO END_____dB.

SPLICE LOSS_____dB. TUBE_____COLOR_____

CABLE NUMBER_____FIBER COUNT_____

TEST CONDUCTOR:_____DATE:_____

CONTRACTING OFFICER'S REP.:_____DATE:_____

SAMPLE DATA FORM

END-TO-END ATTENUATION TEST

BLDG. LOC.__________________________TO__________________LENGTH:__________km.
CABLE NO.______________NO. CONNECTORS______________NO. SPLICES______________
CALCULATED ATTENUATION:_____________Db. TEST REFERENCE LOSS:_____________Db.

FIBER NO.	COLOR: TUBE/ FIBER	FIBER UNDER TEST (Db)	NET LOSS (Db)	FIBER NO.	COLOR: TUBE/ FIBER	FIBER UNDER TEST (Db)	NET LOSS (Db)

TEST CONDUCTOR:_______________________________________DATE:_________________

CONTRACTING OFFICER'S REP.:___________________________DATE:_________________

SAMPLE DATA FORM

END-TO-END INSTALLED BANDWIDTH CABLE TEST REPORT

FROM BLDG.:________________________TO BLDG./END POINT:________________________
LENGTH:____________________km. CABLE NUMBER:___________________________________

CABLE COUNT	TUBE NO.	FIBER NO.	COLOR TUBE/FIBER		BANDWIDTH MHz @ 1300 nm	GHz -km

TEST CONDUCTOR:_______________________________________DATE:_________________

CONTRACTING OFFICER'S REP.:___________________________DATE:_________________

-- End of Section --